Addendum No. 02

to the
Memorandum of Understanding
for Collaboration in the Neutrino Program

WA104

Improving the ICARUS T600 Liquid Argon Time Projection Chamber (LAr TPC) in order to prepare for its operation at shallow neutrino depths.

Considering that:

The Italian Istituto Nazionale di Fisica Nucleare (INFN) and the ICARUS Collaboration have developed the technology of the LAr-TPC. The ICARUS T600 neutrino experiment has successfully completed a three years physics program at CNGS, exposed in the underground Hall B of the Gran Sasso National Laboratory in Assergi, at 730 km to the neutrino beam from CERN, thus demonstrating with all previous activities the very positive assessment of the detection capabilities of the LAr-TPC.

The next step of the ICARUS physics programmes will be dedicated to the definitive search for neutrino related "anomalies" occurring at shorter distances and at a shallow depth from a neutrino beam. A number of different neutrino related "anomalies" have been experimentally reported but not conclusively demonstrated. With the observation of the neutrino oscillations at several suitable distances from the target such as to ensure optimal matching, the novel LAr-TPC technology introduces important new features, which should allow a definitive clarification of all the above described "anomalies". To that effect the Collaboration has been extended by additional teams from the INFN and elsewhere.

On the basis of the Proposals submitted in 2011 and 2012 (P-343, P-345, P-347) and a detailed review of the scientific merits, the technological feasibility and estimates of the needed resources, the SPS Committee (SPSC) has finally recommended the approval of the P-347 Proposal.

The proposal P-347 [1] had foreseen the transport to CERN of the ICARUS T600 detector and the construction of a new detector with sensitive mass about ¼ of the T600 (about 200 tons of liquid Argon), to be combined as far and near detectors in short baseline neutrino beam for sterile neutrinos searches. However the realization of a neutrino beam has not been granted by CERN in a foreseeable future and in order to be performed, the experiment has to be moved elsewhere.

Pending the optimal installation of ICARUS possibly at FNAL, the experiment will be provisionally located and reinstalled at CERN in the "Gargamelle Hall (b185)" with a number of modifications and additions that are hereby described. In particular, the programme still under negotiation under the heading "WA104" will include these modifications for the T600 detector and several other ICARUS related R&D activities on LAr TPC. Several additional and independent R&D activities will be pursued in parallel by several INFN Institutions, especially at LNGS, Padova and Pavia.

Based on the advice of the CERN-SPSC, the CERN-Research Board has recommended to the Director General of CERN to approve the above-mentioned provisional installation at CERN.

With the endorsement of the present Addendum, the President of INFN and the CERN-DG [2,3] have accepted the enclosed program and approved the Research Board recommendation, and are willing to fund the undertaking hereby described.

It is agreed as follows

Article 1: Purpose

1.1 The purpose of this MOU is to lay down the terms of participation of the contributing Institutes and Funding Agencies for the upgrading of ICARUS T600, carrying out the related R&D, in view of the further operation on a short baseline neutrino facility elsewhere at a shallow depth and a short distance from the neutrino beam.

1.2 The subsequent transport of ICARUS elsewhere and the related costs are not part of this addendum.

1.3 All the Annexes are an integral part of this MOU.

Article 2: Parties

2.1 The Parties to this MOU shall be all the Institutes that are contributing to the upgrading of ICARUS T600 and of the related R&D, their Funding Agencies (the Neutrino Funding Agencies) and CERN as the Host Laboratory. The current list of involved Institutes and Funding Agencies is given in Annex 3.

Article 3: Duration

3.1 This activities foreseen in the Addendum take effect from the date of signature and shall remain valid until 31st December 2016. The Addendum can be extended by mutual agreement in writing.

Article 4 : The improvements of ICARUS T600 and of the related R&D

4.1 The work plan consists of a number of sub-units, work packages and/or deliverables provided by participating institutes are listed in Annex 1. The specific support from CERN as a Host Laboratory is also detailed out in Annex 1.

4.2 The management structure of the project is described in Annex 2, as well as list of persons currently holding management positions.

4.3 The technical participation of the Institutes, grouped by Funding Agency, is set out in Annex 3.

4.5 Annex 4 shows the value of the deliverables, by Funding Agency, work packages or deliverables and the human resources to which the involved Institutes, Funding Agencies and CERN as Host Laboratory are committed and for which they have foreseen the appropriate funding.

4.6 The time profile of expenses is shown in Annex 4.

4.7 The schedule for the work packages and the main project milestones are given in Annex 5.

ANNEXES

Annex 1:	Brief description of the main joint contributions within the present Addendum of the MOU
Annex 2:	Organization and Management structure of the Collaboration and persons currently holding management positions
Annex 3:	List of Institutes and Representatives of INFN and other participants to WA104
Annex 4:	Value of deliverables, grouped by Funding Agency and/or sub-units (systems) and payment profile and manpower resources
Annex 5:	Milestones

The European Organization for Nuclear Research (CERN)

and

The INFN, on behalf of the WA104 Collaboration

endorse the Present Addendum to the Memorandum of Understanding with the indicated improvements of ICARUS T600 and with the related R&D on Liquid Argon Time Projection Chamber (LAr TPC).

for CERN 25/11/2014

The Director of Reasearch and Computing

Sergio Bertolucci .....

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For INFN, on behalf of INFN participating Institutes

The President

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ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
Prof. Fernando Ferroni
.....

Signature

Place and Date

ROME 28 NOV. 2014 .....

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ANNEX 1 : Brief description of the main joint contributions within the present Addendum of the MOU.

The T600 detector is presently the largest operational LAr-TPC [4,5]. Over the last three years, the ICARUS collaboration has successfully operated the detector and a LAr mass of 760 t underground in the Hall B of the GranSasso laboratory simultaneously with neutrinos coming both from cosmic rays and from the CERN accelerator. A large mount of physics data has been collected and is presently being actively analysed. Several important papers have already been published or are in preparation.
The ICARUS T600 detector is presently being de-commissioned at the INFN GranSasso underground Laboratory. According to the present MOU, it will be transferred to CERN. The LAr-TPC's will be then upgraded in order to be moved elsewhere in a neutrino beam near the surface and at a relatively short distance from a neutrino target.
The present Addendum to the MOU refers to the financing as in 7.1.1 of the enclosed Memorandum, namely the Common Infrastructure items, comprising the costs that the Collaboration agrees to bear at its common expense. CERN, as the Host Laboratory, will contribute to such costs, subject to prior negotiations with the Collaboration.
There are according to 7.1.2 substantial additional project-specific items that are the primary responsibility of the individual Neutrino Institutions and which shall be the subject of a joint additional Memorandum between INFN and the participating Institutes and eventually CERN. These programmes involve several new R&D developments in continuation with the long term on going activities of the ICARUS team, with for instance in a not inclusive list the introduction of a magnetic field, the use of photo-sensitive dopants, the developments in the electronics since the construction of the T600, replacement the traditional PMTs with solid-state Silicon Photomultipliers (SiPM) for scintillation light and many others.
The T600 will be located inside the existing "Gargamelle Hall" B-185. The activities at CERN should be performed during a relatively short time period of slightly more than two years, in order to ensure the fastest progression and a prompt transfer to the subsequent neutrino location elsewhere. Therefore in particular, no further cooling at cryogenic temperatures is foreseen at CERN. Although one of the more remarkable results of the T600 detector has been the one of an exceptional free electron lifetime exceeding the 20 meters path, in order to move the experiment as quickly as possible elsewhere, it has been decided to maintain unchanged the present inner detector configuration of 1.5 m drift path and to introduce no modification to the already working sensitive structure of the LAr-TPC, however with the necessary replacement of broken connecting cables. Therefore the changes required by the future operation of the detector at shallow depths will be mainly realized within the outer shells of the structures. More precisely they are:
1) A new photomultiplier (PM's) and far more sensitive arrangement will be introduced and shifted from the VUV to the visible light with an appropriate deposit of the PM's in the presently existing locations, beyond the drift wire planes. In the original CNGS configuration the full light from each of the two T300 was collected globally. The purpose of the new PM's in the higher background conditions at a shallow depth is the one of locating the position of the centroid of the collected "trigger" light in the three dimensions (both

longitudinally and transversally) with an accuracy well below the average distance between cosmic ray related muon tracks.
2) A new finely segmented 4π anticoincidence shield is installed at the periphery of the LAr of the cryostats, in order to efficiently detect and reject incoming cosmic rays and other charged particles traversing the periphery of the LAr volumes. On the bottom and on the four lateral sides one will insert inside such a box, a few centimetres away from the edges, a large number of finely segmented thin counter plates parallel to the walls, in order to detect the presence of the dE/dx signals generated by the electrons in the LAr. The top face is more delicate and it is carried out with an external wide RPC counter arrangement or equivalent as the best way of achieving a realistic coverage.
3) The ICARUS T600 electronics was successfully designed starting from an analogue low noise "warm" front-end amplifier followed by a multiplexed 10-bit AD converter and by a digital VME module that performs local storage and data compression. The overall architecture might be also appropriate at the future shallow depths, although about 15 years old and based on VME standards. However for a LAr TPC whose lifetime is the order of tens of years, the maintenance of the old electronics is an issue. The failure rate of electronics component is high at early stage of operation then lowers and after long time rises again, so called phase 3. A new electronics based on the same concept but designed with new more performing components, adopting a modern switched I/O bus and parallelization of data flows, is already under test. The adoption of this system requires an intervention of the internal wiring of the detector easy to be performed during T600 overhauling at CERN, not trivial with detector closed. The decision about which electronics to adopt is postponed to evaluate the performance of the new system and its exact cost. The related funding eventually will be part of a dedicated annex to the MOU.

A further R&D cooperative program could be initiated within the WA104 program in order to explore the feasibility and performances of a cold, more compact electronics. This would imply improvements of the signal to noise ratio, shortening the length of signal cables, and a lower power consumption.

References

[1] ICARUS-NESSIE Collaborations, "Search for anomalies from neutrino and anti neutrino oscillations at $\Delta m^2 \approx 1eV^2$ with muon spectrometers and large LAr–TPC imaging detectors. Technical proposal.", CERN-SPSC-2012-010 and SPSC-P-347 (2012)

[2] CERN-DG-RB-2013-438 Minutes 205

[3] R. Heuer, Memorandum DG/2013/263, September 2013

[4] S. Amerio et al. (ICARUS coll.), Nucl.Instrum.Meth. A527 (2004) 329-410

[5] C. Rubbia et al. (ICARUS coll.), JINST 6 (2011) P07011

ANNEX 2: Organization and Management structure of the Collaboration and persons currently holding management positions

The persons listed in ANNEX 3 presently represent the collaborating Institutions. Any change of representation shall be notified to the Collaboration Board Chairman in writing.

Collaboration Board Chair & Spokesperson: *Carlo Rubbia*

Deputy Spokesperson: *Sandro Centro*

Technical Coordinator and GLIMOS to be elected by the collaboration after the approval of the present document.

ANNEX 3:

List Institutes and Representatives of INFN

1. ***INFN, LNGS***, *Assergi (AQ), Italy,*
   represented by Chiara Vignoli
2. ***INFN, Sezione di Padova***, *35131 Padova, Italy,*
   represented by Alberto Guglielmi
3. ***INFN, LNF***, *00044 Frascati (Roma), Italy,*
   represented by Pio Picchi
4. ***INFN, Sezione di Pavia***, *27100 Pavia, Italy,*
   represented by Claudio Montanari
5. ***INFN, Sezione di Milano Bicocca, Dipartimento di Fisica G. Occhialini***, *20126 Milano, Italy,*
   represented by Maurizio Bonesini
6. ***INFN, Sezione di Milano,*** *20133 Milano, Italy*
   represented by Paola Sala
7. ***INFN, Sezione di Napoli***, *80126 Napoli, Italy,*
   represented by Alfredo Cocco
8. **Gran Sasso Science Institute** (GSSI), L'Aquila, Italy
   represented by Carlo Rubbia
9. ***CERN,*** *Geneva, Switzerland,*
   represented by Marzio Nessi

Other international Institutions have expressed interest in the project and their appointment will be regulated by ad hoc documents.

ANNEX 4: Value of deliverables, grouped by Funding Agency and/or sub-units (systems) and payment profile and manpower resources.

#	item	cost KCHF	INFN (%)	CERN (%)	start	end	CERN/ INFN costs
	T600 movement to CERN						
1	Laser survey	16	0	100	Oct-13	Oct-13	16
2	Transp. Frames engineering	23	100	0	Oct-13	Dec-13	23
3	2 x Transp. frames procurement	250	0	100	Mar-14	Aug-14	250
4	Disassembly work + TPC extraction	575	100	0	Oct-13	Dec-14	575
5	1st TPC transport to CERN	69	0	100	Nov-14	Nov-14	69
6	2nd TPC transport to CERN	69	0	100	Dec-14	Dec-14	69
7	Equipment transport to CERN	125	100	0	Nov-13	Dec-14	125
8	185b preparation	100	0	100	Nov-13	Dec-14	100
	total	1227					504 / 723
	T600 cryostats						
9	Engineering cold vessel + production follow up	200	25	75	Jan-13	Sep-16	150 / 50
10	Engineering cold vessel supports	24	0	100	Jan-13	Jun-14	24
11	Engineering warm vessel (IPJAS)	120	0	100	Jan-14	Oct-15	120
12	GTT preliminary study	31	0	100	May-13	Dec-13	31
13	Procurement Extruded Aluminium	450	100	0	Dec-14	May-15	450
14	Procurement Cold Vessels	1225	100	0	Dec-14	Sep-16	1225
15	Vessel components transport to CERN	69	0	100	Jul-15	Aug-16	69
16	Cold Vessels final assembly at CERN	350	0	100	May-15	Dec-16	350
17	Procurement Warm Vessel + support	725	0	100	Dec-14	Mar-16	725
18	Procurement Insulation	447	0	100	Jan-15	Nov-15	447
19	Warm vessel assembly	88	0	100	Oct-15	Jun-16	88
20	Insulation installation	156	50	50	Sep-16	Dec-16	78 / 78
21	Cold shields	66	100	0	Jan-15	Dec-16	66
	total	3951					2082/1869

	T600 cryogenics						
22	Reorganization and packaging	313	0	100	Jan-15	Dec-16	313
23	New hardware	425	0	100	May-15	Oct-16	425
24	Tests and maintenance	250	0	100	Jan-15	Mar-16	250
25	Cryo group at CERN (1 PJAS)	120	0	100	Mar-15	Oct-16	120
26	Vacuum test	0	50	50	Aug-16	Nov-16	0
27	Cold gas test	0	50	50	Nov-16	Dec-16	0
	total	1108					1108/0
	T600 refurbishing						
28	Clean room in b185 + expert manpower	391	20	80	Oct-14	Nov-16	313/78
29	Crane drivers and internal transport	200	0	100	Oct-14	Dec-16	200
30	TPC-1 Cabling TPC internal	31	100	0	Dec-14	Aug-15	31
31	TPC-1 New PM procurement	750	100	0	Oct-14	Aug-15	750
32	TPC-1 New PM installation	39	100	0	Mar-15	Sep-15	39
33	TPC-1 installation in cold vessel	30	50	50	Nov-15	Jan-16	15/15
34	TPC-2 Cabling TPC internal	31	100	0	Jan-16	Oct-16	31
35	TPC-2 New PM procurement	750	100	0	Oct-15	Jul-16	750
36	TPC-2 New PM installation	39	100	0	Feb-16	Oct-16	39
37	TPC-2 installation in cold vessel	30	50	50	Nov-16	Dec-16	15/15
38	Final assembly into the warm vessel	0	50	50	Dec-16	Jan-17	
39	Veto counters procurement and preassembly	1200	50	50	Aug-15	Dec-16	600 / 600
40	R&D for a future upgrade	240	50	50	Jan-15	Dec-16	120 / 120
	total	3731					1263/2468
	T600 controls and tests						
41	Team manpower (1 PJAS)	90	0	100	Sep-15	Dec-16	90
42	Slow Controls hardware	25	0	100	Jan-16	Nov-16	25
43	Slow Controls software	0	50	50	Jan-16	Nov-16	0
44	DAQ system	0	50	50	Jan-16	Nov-16	0
45	Tests of Slow Controls	0	50	50	Jan-16	Nov-16	0
46	Tests of DAQ	0	50	50	Jan-16	Nov-16	0
	total	115					115
	Gran Total T600 (KCHF)		**INFN Contrib.**		**CERN Contrib.**		
	10132		**5060**		**5072**		

ANNEX 5: Project Milestones

1. First T600 TPC transport to CERN: November 2014
2. Second T600 TPC transport to CERN: December 2014
3. First T600 aluminum vessel ready at CERN: October 2015
4. Second T600 aluminum vessel ready at CERN: October 2016
5. First T600 TPC ready for insertion in the new cold vessel: November 2015
6. Second T600 TPC ready for insertion in the new cold vessel: November 2016
7. T600 ready for transport to FNAL: beginning 2017